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Vibration Analysis of 5-Axis Articulated Robot

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Abstract: *During its operation, a power transmission belt can undergo axial, transverse and torsional motion. A detailed vibration analysis of 5-axis articulated robot was conducted. Results show thatpower transmission belt drives majorly contributed to the vibration in robots. Experiments were conducted through which we concluded that belt elongation due to applied tension caused vibrations. The system was further analyzed to know the elongation and natural frequency of the belt. Modifications done to the system by using spring loaded idler that would automatically adjust the belt tension, reduce vibrations in the system, increase life of the belt and in turn reduce the maintenance cost of robot.*
Keywords:*Belt, Elongation, Robot, Vibration.*

I. Introduction

The pulley– belt framework is a critical mechanical segment for transmitting power in numerous applications, for example, in band saws, attractive tape, and in the field of material assembling. Specifically, this framework serves to exchange torque from a motor to auto alternators, pumps, compressors, and fans. Vibrations created by pulley– belt frameworks deliver an unsavory commotion and make harm the frameworks. At the point when these vibrations happen in frameworks that require perplexing, exact, or maintained operation, they go about as a factor that corrupts the execution. Consequently, inquire about on the dynamic qualities of the pulley– belt framework is vital to enhance the steadiness and precision of pulley– belt frameworks in working conditions. Various scientists throughout the hundreds of years have directed studies including the dynamic investigation of pulley– belt frameworks.

II. Literature Review

In the underlying investigations, specialists displayed the pulley– belt framework by considering the belt as a string that does not have twisting solidness. Beikmann[1, 2] displayed the belt as a string and explored the dynamic attributes of a three-pulley framework made out of two pulleys and a tensioner. They broke down the impacts of the tensioner on the characteristic frequencies and mode shapes and led an examination exploring the tensioner plan with a specific end goal to keep a consistent pressure connected to the belt paying little heed to changes in the moving pace and frill torque of the belt. Eliseev and Vetyukov [3] presented a nonlinear model of an extensible versatile string to depict the belt reaching with the pulley. They tackled the changed conditions for an ideal contact between the pulleys and belts and researched the reliance of the maximal transmitted minute on the rakish speeds of the pulleys and on the pre-pressure of the belt. From an alternate perspective, Kong and Parker [4] displayed the belt in a three-pulley framework by incorporating a bowing firmness in the model. They examined the impact of the twisting firmness of the belt on the harmony diversion in steady state conditions and guaranteed to have the capacity to show critical blunders if the bowing solidness was ignored.

Research has additionally been conveyed to explore the supporting states of the pulley– belt framework and their consequences for the dynamic conduct. Parker [5] built up a model for a pivotally moving string on a flexible establishment and researched the dependability through eigenvalue examination. He found that there is just a single basic speed when the string is unsupported, though there is an extra basic speed bigger than the basic speed of the unsupported string. Perkins [6] demonstrated a string moving pivotally over a versatile establishment and dissected the regular frequencies and mode shapes when the establishment firmness, establishment geometry, and moving rate of the string are changed. Ravindra [7] considered the pulley– belt framework in which the lower belt has a ground firmness. They examined the impact of the ground firmness on the normal frequencies and harmony diversion. Afterward, Lee and Kim [8] changed the one-dimensional spring to a two-dimensional spring. They broke down how changing the parameters affected the regular recurrence by utilizing free vibration investigation. They likewise led constrained vibration examination to explore the impact of the belt compose on the vibration separation for the transverse vibration. Ding [9] connected intermittent movement to the establishment supporting the pulley– belt framework and broke down the impact of the excitation compel on the framework.

1.1 Purpose

Current system incorporates an idler and two pulleys. Repeatability tests were carried out which gave possibility for two failure criteria viz; motor brakes or belt elongation. The tests were conducted over a period of 8 days that nullified the option of motor brakes. The conclusion drawn was that the belt majorly contributes to the vibrations in the robot. Due to prolonged use, the belt undergoes elongation that further increases vibration. Main objective of this paper is to reduce or eliminate the vibrations induced in the belt-pulley drive by introducing a spring-loaded idler pulley. Other objectives include automatically adjusting the tension in the belt, increasing the life of belt and reducing maintenance cost occurred.

1.2 Contribution of the paper

This paper contributes to the optimization in mechanical design of 5-axis articulated robot. The modification in the system increases the life of belt 5 times that of now depending on the belt material and its elongation. This reduces maintenance cost and profits the manufacturer.

2. Existing System

The existing system incorporates two pulleys and one idler pulley. The belt is made of material Sincroflex Gen 3 which uses steel reinforcements. According to the standard, the belt is discarded after it undergoes a deflection of 0.1mm. The pulleys are made of aluminum that make it light in weight and durable. Following are the specifications of the system:

2.1 Driving Pulley

Number of teeth = 20
Diameter = 31.83mm
Speed = 270rpm

2.2 Driven Pulley

Number of teeth = 40
Diameter = 143.24mm
Speed = 60rpm

III. Calculations

2.3 Resolving Belt Tensions

The value for belt tension when the idler is engaged is calculated experimentally using vibrameter.

2.4 Calculate force acting on idler

The forces acting on the belt are resolved using D’AlambertPriciple,

$$\Sigma Fx = 0$$
$$\Sigma Fy = 0$$

From this, we find Compression Force (P) acting on the idler

2.5 **Design of spring**

2.5.1 Velocity of Belt (V_B)

$$V_B = \frac{\pi d n}{60000}$$

2.5.2 Centre Distance (CD)

Centre Distance is taken in accordance with the space available in the component.

2.5.3 Centrifugal Tension (T_C)

$$T_C = m.V_B^2$$

2.5.4 Angle of Contact ()

$$\alpha = \sin^{-1}\frac{D-d}{2c}$$

2.5.5 Limiting Tension Ratio

Take values from catalogue of belt material used.

2.5.6 Power

$$P = (T_t - T_s).V_B$$

2.5.7 Spring Factor

Spring Factor to be decided according to the application of the spring

2.5.8 Wahl Factor

$$k = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

2.5.9 Wire Diameter

$$\tau = k(\frac{8PC}{\pi d^2})$$

2.5.10 Validation of design

$$\tau_{induced} < \tau_{permissible}$$

2.5.11 Deflection in Spring

$$\delta = \frac{8PD^3N}{Gd^4}$$

IV. Conclusion

With the addition of spring tensioner to the system, the belt life increases significantly. The total vibrations in the system reduces and thus reduces the cost of maintenance of the robot. The main objective of the spring tensioner is to automatically adjust the tension in the belt for elongation in the belt. The system is designed as per the requirements of the robot being tested. The method for designing has also been discussed in the paper.

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